NONDESTRUCTIVE DETERMINATION OF HEAT/FIRE DAMAGE TO POLYMER-MATRIX COMPOSITES USING OBLIQUELY INSONIFIED ULTRASONIC WAVES

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ABSTRACT

Heat and fire damage to composite structures cause loss of strength that cannot be detected by current NDE methods unless physical damage occurs. Further, there is a lack of fundamental understanding of the mechanism of damage from thermal exposure of organic matrix composites to elevated temperatures. Information compiled from field reports and lab experiments increasingly suggests that there is material degradation and it is not necessarily involved with the introduction of physical defects. In recent years, various researchers examined the potential to identifying thermal degradation to organic matrix composites prior to delamination. The methods that were used include: ultrasonics, backscattered X-ray, eddy current, thermography, drift and FPF spectroscopes, acousto-ultrasonics and hardness testing. None of these methods were able to correlate NDE results with loss of mechanical properties.

The authors investigated the potential of obliquely insonified ultrasonic waves as an NDE method for fire/heat damage. This method induces various modes that interact elastically/mechanically with the matrix, fibers and their interface both on the micro and macro levels. Theoretical model was developed to predict the wave behavior in composites and an inversion algorithm was developed to determine the elastic properties. The material is assumed transversely isotropic, namely requiring five elastic coefficients, including C_{11}, C_{12}, C_{22}, C_{23} and C_{55}. The authors investigated the sensitivity of the measurements to variations in these elastic constants and found that this method is very sensitive to the matrix dominated properties (i.e., C_{22}, C_{23} and C_{55}). Since fire/heat damage is mostly a matrix and matrix/fiber interface deterioration, this capability is satisfactory.

To examine the effect of thermal exposure, graphite/epoxy samples were made of AS4/3501, $[\pm 45/90/0_4/\pm 45/0_3]_S$, and $[0]_{24}$ laminates, both 24 layer thick. The samples were exposed to temperature levels above 450°F, tested ultrasonically in the frequency range of 1 to 10 MHz, and the elastic constants were inverted. Test results have shown that ultrasonic oblique insonification has the potential to provide an effective NDE tool for heat/fire damage. Comparison of the properties before and after thermal exposure showed a significant change in the constant C_{22}. This constant is related to the transverse Young's modulus of the laminate and it is the constant that is the most sensitive to the variations in the matrix properties.

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